MICROSHUTTER ARRAYS FOR THE NGST NEAR INFRARED MULTI-OBJECT SPECTROMETER

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ABSTRACT

Field selectors can greatly improve the overall performance and versatility of multi-object spectrometers because they allow efficient use of the available detector arrays and data handling capabilities. Here we describe a programmable multi-object field selector currently under development for use in the NGST Near Infrared Spectrometer (NIRSpec). This device is a large microshutter array of 100µm x 100µm shutters fabricated using Micro-Electro-Mechanical Systems (MEMS) techniques. The microshutters are magnetically actuated and electrostatically latched in their programmed positions. In this paper, we will discuss the design, development, performance, operation, as well as the integration and testing of these microshutter arrays.

INTRODUCTION

Very large two-dimensional arrays of near infrared detectors are now available and find application in many astronomical instruments. However, to obtain the greatest benefit from these arrays, additional components are often required. Low power cryogenic front end electronics and multiplexors are needed to provide low noise readouts and minimize wire count into cryostats and additional optical elements such as micromirrors and microshutters are needed to allow some astronomical instruments to maximize the advantage that these large detector arrays can provide.

The NGST Design Reference Mission (DRM) calls for NSGT to image the universe in three dimensions by using a near-infrared spectrometer to study the spectra of galaxies, clusters and large scale structures in the universe. While the sky is filled with galaxies and clusters of galaxies at the sensitivity which NGST will achieve[1], the filling factor of high redshift objects in a typical field of view is about 5% even at magnitude AB=30. To make efficient use of the large detector array to obtain low and moderate resolution spectra, a field selector is required that allows object selection to focus the power of NGST on the objects of greatest interest.

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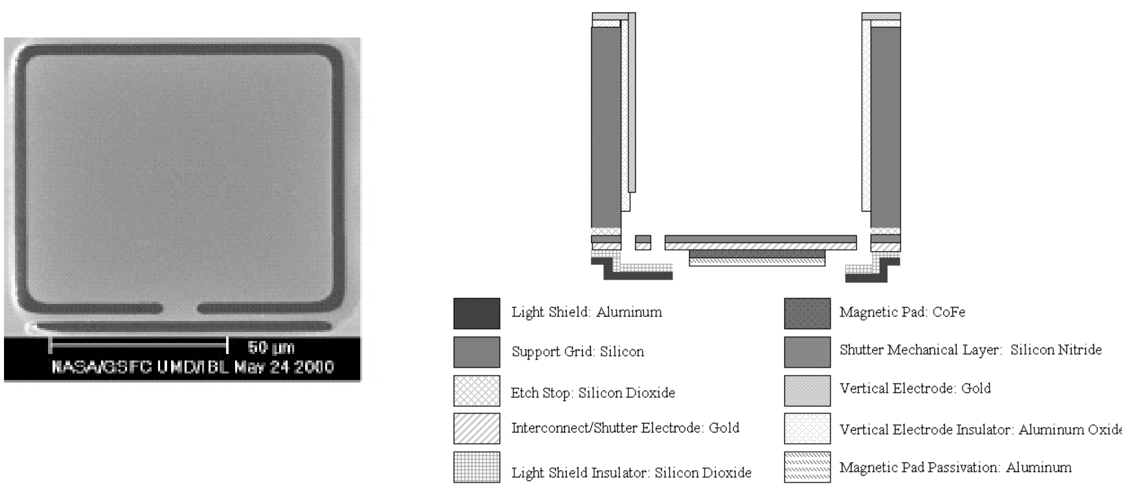
Transmissive field selectors offer higher contrast, lower diffracted and scattered light, and simpler optical design than reflective devices. The primary operational goals of the NIRSpec are high sensitivity, wide spectral coverage, and a minimum of 100 objects in spectral mode. The NGST Science Working Group has selected GSFC to develop a cryogenic fully programmable microshutter array for possible use as the field selector for the NIRSpec instrument. In the paper we describe the development of a space flight qualified cryogenic microshutter array that is designed for use as the field selector for the NGST Multi-Object Spectrometer (MOS).

MICROSHUTTER DESIGN

In contrast to the limited rotation required of micromirrors, each microshutter blade (microblade) must rotate through a large angle (t 90^{o}). Structures used for addressing, actuation, and latching the microshutter in the programmed position must be hidden between shutter blades or on the shutter blades themselves so that they are not in the optical beam when the shutter is in the open position. The design of a single microshutter must be simple and easy to reproduce reliably using standard microelectronic production techniques.

We have satisfied these requirements using a design with a torsion hinge attached at the center of one side of the microblade (see Figure 1). This design allows the large angular deflection required to hide the microblade out of the optical beam and minimizes stress concentrations in the torsion hinge. Calculations and tests showed this design is rugged and can withstand repeated deflection without damage[2,3]. The use of appropriate coatings provides the capability for actuation and latching.



(a) ***(b)***

Figure 1: *(a) Front view of single microshutter. The microshutter is constructed on silicon nitride. The torsion hinge is visible near the bottom of the figure and has electrical leads on its underside to allow electrostatic latching. (b) Cross sectional view of the microshutter. The vertical wall on the left is coated with gold to make it conductive for electrostatic latching when the shutter is positioned near the wall by the magnetic actuation. The light shield at the bottom prevents light leakage through the gaps around the shutters and therefore increases optical contrast.*

FABRICATION

To repeatedly provide the large angle deflections needed, a very thin and strong material is required. We are currently using 0.5µm silicon nitride and are studying designs for 0.25µm material. The entire array is constructed on this material using photolithographic techniques. As received from the manufacturer, the thin silicon nitride is deposited on 100µm thick silicon and this silicon is removed during the processing except around the edges of each shutter where it forms a honeycomb structure of square compartments around each microshutter cell. This honeycomb strengthens the large area of the array. Figure 1(a) shows a photograph of a single cell in an array and 1(b) shows a schematic of a cross section of a single shutter. Each shutter is coated with a thin (0.2µm thick) layer of CoFe (90%-10%) to provide high permeability to the shutter blades so magnetic actuation is possible. An aluminum light shield is placed on each shutter aperture to reduce light leakage when the shutter is closed and give higher contrast between open and closed transmissions. An aluminum coating on the microblade is brought out on a column line and provides electrical contact to each microblade. All the microblades contacts in a column are common. Similarly, the vertical wall on the torsion hinge side in the silicon supporting structure is coated with gold to provide electrical contact. The wall electrodes are common by row and a single lead is brought out for each row. This arrangement allows any microblade to be latched by properly sequencing the voltages on the vertical wall electrodes and shutter blade electrodes.

ACTUATION AND LATCHING

The shutters are actuated by first applying voltage, V_1, to all row lines and voltage, $-V_1$, to all column lines. A potential difference of $2V_1$ between the vertical sidewall and the microblade is adequate to capture the microblade in the open position. The CoFe coating on each microblade allows a significant torque to be applied to the shutters by a strong magnet with a field tailored for our purpose. As the magnet is scanned across the array, the microblades in a column are brought to more than 90^o and are electrostatically latched in the fully open position by the potential between the microblade and the vertical wall. Once all shutters are in the open position, the columns are ready to be programmed as shown in Figure 2.

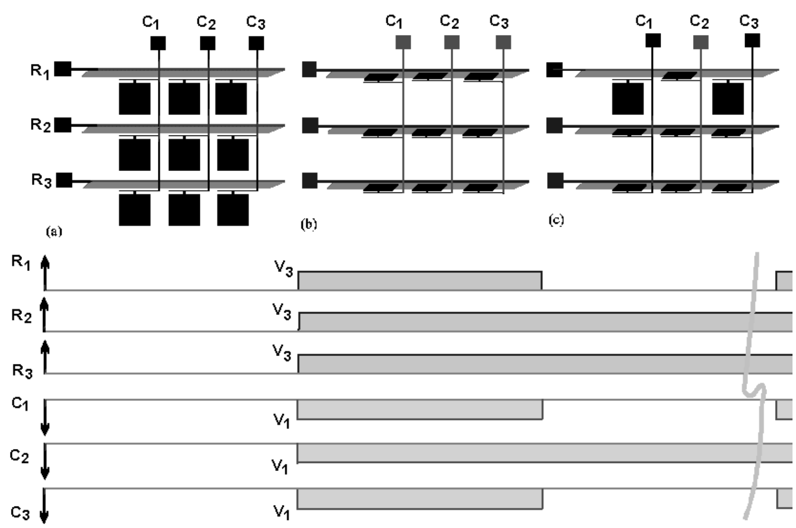


__Figure 2__. The addressing and latching scheme is shown in this figure. With no voltages applied to the row (R) and column (C) lines all shutters in the array are in the closed position (a). Voltage, $-V_1$, is applied to all column lines and V_3 is applied to row lines. The tailored magnet is then swept across the array causing all shutters to open and then they are electrostatically latched in the open position (b). After the magnet is returned to the home position out of the optical path, the rows are programmed one at a time. To address a row, the row's voltage is set to zero. Column lines are then set to zero to close a shutter on the selected row or are maintained at $-V_1$ to leave it open. Microshutters in unaddressed rows are unchanged because the potential difference required for holding a shutter open is much less than either V_1 or V_3.

After programming is completed, all column and rows are returned to their respective latching voltages. The programmed positions are now stable and observations may begin.

SUMMARY

The microshutter array currently under development is a fully addressable close-packed 128x128 array of 100µm x 100µm microshutters designed for cryogenic operation. These initial test arrays have been built with all addressing lines common so individual microshutters are not programmable yet. Portions of these arrays have been magnetically actuated with a small test magnet and electrostatically latched at room temperature. A successful cryogenic (T~30K) actuation and latching test of one of these arrays was also recently completed. Tests of some cryogenic addressing electronics have been done and these convenient low power commercial parts are currently being tested for radiation hardness at a particle accelerator to determine if they are suitable for the radiation environment in space.

Our goal for the NIRSpec flight array is a 2048 x 1024 microshutter array consisting of 16 sub-arrays of 512 x 256 in a mosaic. In the 512 x 256 arrays, the shutter dimensions will be 100µm x 200µm. For the 128 x 128 arrays currently being built the shutter's filling factor is greater than 80%. The final arrays will have a slightly higher filling factor due to the larger microblades of this configuration. Optical tests show that the contrast (ratio of open to closed transmission) is about 3000, exceeding the NGST minimum requirement.

A ground-based demonstration of the devices is also planned. The Rapid Infrared-Visible Multi-Object Spectrometer (RIVMOS)[4] operating in the 0.6-5µm wavelength range will use a 512 x 256 microshutter array as the object selection device in conjunction with a 1024 x 1024 InSb Aladdin detector array. RIVMOS should demonstrate the versatility and high efficiency that these microshutter arrays will bring to the NGST NIRSpec.

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REFERENCES

1. H. Stockman, *The Next Generation Space Telescope: visiting a time when galaxies were young*, The Association of Universities for Research in Astronomy, Inc., 1997
2. S. Moseley et al., "Programmable 2-dimensional microshutter array", *ASP Conference Series*, 1999
3. R. Fettig, S. Moseley, A. Kutyrev, J. Orloff, J. Kuhn, and L. Shude, "Some aspects of the mechanical analysis of microshutters", in *Materials and Device Characterization in Micromachining II, Proceedings of SPIE* **3875**, 1999
4. A.S. Kutyrev et al., "RIVMOS - Rapid Infrared-Visible Multi-Object Spectrometer", in *BAAS*, V 33, No 2, 2001